VOL. IX. No. 3. FEBRUARY 1, 1912

THE JOURNAL OF PHILOSOPHY
PSYCHOLOGY AND SCIENTIFIC METHODS

DOCTRINE OF SPECIFIC NERVE ENERGIES

THE doctrine of specific nerve energies was first definitely formulated by Johannes Müller (1801–1858). Physiologists before his time had regarded the sense nerves as merely conductors, each of which, however, had a special sensibility to some peculiar impression, and hence was the mediator of some definite quality of *external* bodies. Müller pointed out that the discovery of the possibility of arousing different sensations in different nerves by the same stimulus, *e. g.*, electricity, and also of the fact that different stimuli, *e. g.*, electrical and mechanical, can produce in the same sense organ similar sensations, had rendered the theory of the susceptibility of nerves to certain impressions inadequate and unsatisfactory. He therefore advanced the theory that "each peculiar nerve has a special power or quality, which the exciting cause merely renders manifest"; and that in sensations we do not experience the qualities or states of external bodies, but merely the conditions of the nerves themselves. Hence light, sound, and other apparently external qualities, as such, have no existence, but are states which certain unknown external influences excite in our nerves.

It is clear that Müller considered the sensory nerves themselves as the seat of the "specific energy"; and thought that the function of the central organ consisted in the connection of the nerves into a system, the reflection of the sensations upon the origin of the motor nerves, ideation, remembrance, and attention. His theory, also, seems to refer to modality only and not to quality; that is, a single specific nervous energy is provided for each sense organ; and, therefore, any sensory apparatus may respond to different forms of adequate stimuli in a variety of ways.

Helmholtz first distinguished between modality and quality. Sensations differ in quality when it is possible to pass by a series of intervening sensations from one to the other. They differ in modality when this can not be done, *e. g.*, visual and auditory sensations. Helmholtz attempted to explain *quality*, also, by postulating

a specific energy for each nerve *fiber,* that is, he sought for specific energies within the individual sense organs; and his theories of visual and auditory processes depend upon this further application of the doctrine, *e. g.,* each of the colors, red, green, and violet, depends upon a specific process. Helmholtz must have interpreted the law somewhat differently from his predecessors, for he regarded these specific differences in *quality* as determined by the character of the *external* physical stimulus. In apparent contradiction to this he held that *modality* was exclusively subjective. But if quality depends upon external stimuli, the same must be said of modality, for the latter is a mere concept or general term. There is no such thing as tasting in *general* or seeing in general. What we taste or see is always a *particular* quality.

Before proceeding we must refer to a certain ambiguity in the term "specific energy." It confuses *function* with property or quality. It makes, of course, a great deal of difference whether *specific property* or *specific function* is meant by the phrase. Most writers on the subject have used the term so loosely that it is difficult to know just what they mean when they speak of "specific energy." Wundt would scarcely deny the specific energy, in the sense of specific *function,* of any given nervous unit; but he would deny it in the sense of a specific property, that is, specific chemical or physical process, in that unit as a correlate of a specific quality of sensation. Of course the latter meaning includes the former, but the opposite is not true—at least not necessarily so. Müller meant by the doctrine a specific nervous process, and so, we think, did Helmholtz.

McDougall leaves no doubt as to his position when he says: "The nervous *process* which is the immediate exciting cause of each quality of sensation is different from that which excites any other quality of sensation"; and that "it is a difference which could, if we knew more about it, be expressed in physical or chemical terms." He advances the following proofs for his theory: (1) Whenever it has been found possible to stimulate a nerve or sense organ by inadequate stimuli, the resulting sensation is of a similar quality to that produced by stimulation of the same nerve or sense organ by its adequate stimulus, that is, the one that normally excites it. (2) The Helmholtz theories of visual and auditory processes, which offer the most satisfactory explanation of the facts (?), depend upon this doctrine. (3) Unlike effects must have unlike causes, therefore unlike sensations must depend upon unlike nervous processes.

McDougall differs from Müller in placing the seat of the specific energy not in the nerves themselves, but in the cerebral cortex, and especially in the synaptic processes. His reasons for so doing are as

follows: (1) If the specific quality were in the nerves or sense organs, we would have to consider these processes as directly affecting consciousness. This is improbable since loss of a sense organ or nerve does not prevent the recurrence of the same quality of sensation in imagination, while loss of the cortical structure does. (2) The conduction processes of all sensory nerves appear similar in kind. (3) It is in harmony with the principle of strict localization of cerebral functions and the principle of association; for if the cortex were of indifferent function, it would be difficult to understand why the excitement of an associated group might not on one occasion be accompanied by one sensation, and on others by entirely different sensations or psychical states. (4) This specialized character belongs to the synapse, because the nerve cells are anatomically similar and have as their function to preside over nutrition; also the synaptic processes are highly fatiguable and transmit the nervous impulse discontinuously. These features seem likewise characteristic of psychical phenomena.

It is noteworthy that as our knowledge of the processes concerned has advanced, the seat of the specific quality has receded from the nerves to the cell-bodies and thence to the synapse. That is, with the progress of physiology and anatomy, the advocates of the theory have been forced to withdraw this *qualitas occulta* from known to unknown regions. It seems likely, as Wundt remarks, that in the future the specific energy will be placed in the sense organs themselves, where differences of structure and function warrant the assumption.

Wundt holds that the different qualities of sensations depend *not* on the specific *character* of nervous elements, but solely upon the different modes of their connection. The principle of connection of elements asserts that the "simplest psychical content has a complex physiological substrate," *e. g.,* the sensation of red has a complex connection of nervous elements as its physical correlate. It is not, however, so much the connection of nerve elements with one another, as their connection with organs and tissue elements and through these with external stimuli, that determines the specific quality of sensation. A specific physical or chemical process as the basis for each primary quality of sensation is an *unnecessary* hypothesis which involves many difficulties and is wholly unprovable. True, certain connections or systems of elements have specific functions, which, however, have been acquired under pressure of the external conditions of life.

This leads to the hypothesis of the original indifference of function, which is founded upon the following observations: (1) A fairly long continuance of any function is necessary before the correspond-

ing sense qualities appear in imagination, *e. g.*, if a person becomes blind in *early life,* he has no visual imagery. (2) Functional disturbances occasioned by lesions are sometimes removed by a *vicarious* functioning of other elements. Here the specific function arises during the lifetime of an individual. Of course we *inherit dispositions,* which consist in the connection of nervous and tissue elements, etc.; but, even so, the development of their specific functions demands the actual discharge of these functions upon excitation of the end organs by external stimuli.

The indifference of elementary function (and certainly property) is also proved anatomically by the essential identity of structure; physiologically, by the essential *identity* of nervous processes; and psychologically, by the fact that elementary qualities of sensation are referred to functions of peripheral elements.

The doctrine of specific nerve energies is contrary to the physiological doctrine of the development of the senses and hence to the whole theory of evolution. According to the latter our various senses arose through differentiation from a common sensibility—a differentiation due to the action of external stimuli upon the organism, and the adaptation of the latter to a complex environment. Hence each sense organ is excited only by those stimuli to which it has become specially adapted, and is unaffected by others. Even the sense organs, then, are only secondary in determining the qualities of sensations. These must ultimately be referred to external stimuli. The specific character of the sensation most probably consists in the *attitude* which we assume towards the external stimulus—an attitude determined by the *connection of nervous* and other elements.

We remarked above that each sense organ or nerve was excited only by its adequate stimuli, but it is just because there are exceptions to this rule that the doctrine of specific energies was first formulated. Electrical stimulation will produce sensations of light, taste, or smell, etc. Mechanical stimuli will produce visual or auditory sensations; direct electrical stimulation or section of the nervus opticus will "cause flashes of light"; and it is said that mechanical, chemical, or thermal excitation of the chorda tympani will produce sensations of taste. These are the chief facts that can be brought to bear in favor of the theory, and which any other theory must endeavor to explain; but even if otherwise inexplicable, they can not be regarded as proofs of the doctrine, but merely as illustrations.

According to Wundt, all these cases of abnormal stimulation can be explained by the principle of "practise and adaptation." The impressions which the sense organs are adapted to receive, by virtue of inherited or developed *connections of elements,* arouse certain sensations; and when this mode of responding has become habitual,

the accustomed excitation is set up by inadequate stimuli. Külpe says that sensory nerve fibers with centrifugal conduction have been demonstrated in the case of the nervus opticus, and that the visual sensations aroused by electrical stimulation of this nerve are due to the fact that the nervous excitation is first conveyed to the retina by these efferent sensory fibers, and thence pursues its normal or accustomed path of discharge. These centrifugal fibers may exist in all sensory nerves; but even if they do not, the alternative theory that stimulation arouses the accustomed excitation in the visual system of elements is not difficult; and far simpler than the theory of a *qualitas occulta* different for every primary quality of sensation.

If the doctrine of specific energies were true, we see no reason why there would not be a much more far-reaching *indifference of the stimuli* than is actually the case. The inadequate stimuli are limited in number, and there are many *negative instances* against the theory: *e. g.,* mechanical stimuli will not produce sensations of taste or of smell; sound waves will not affect the nervus opticus, nor light waves the auditory nerve; temperature stimuli will not arouse other sensations, etc.

When electricity arouses the sensations of taste and smell, it may only prove that it is an *adequate* stimulus for these sensations, that is, that electricity can be tasted and smelt. There is at least nothing extraordinary in regarding electricity as an adequate stimulus for sight. Electrical and light waves are not essentially different; and, especially if one adopts Meisling's vibratory theory of vision, this conclusion appears highly plausible.

Then again an inadequate stimulus may contain within itself or give rise to the usual normal stimulus: *e. g.,* when a sensation of sound is produced by mechanical pressure, this may be due to sound waves produced in the inner ear by external pressure upon the organ of hearing; and when electrical stimulation produces a taste sensation, this may be due to a decomposition of the saliva, which frees the adequate stimulus.

A final objection against the indifference of the stimuli—or rather against the effects of inadequate stimuli as supposed by the doctrine of specific nerve energies—is a psychological one which seems to us of considerable importance. It seems introspectively untrue that adequate and inadequate stimuli produce sensations that are at all or essentially the same in character. There is always a quality or feeling associated with sensations produced by the latter, by which they can clearly be distinguished from sensations produced by the former. We are never deceived in this respect; and it certainly rests with the advocates of the doctrine to explain why this is so. If the theory were true, it would be difficult to understand why inade-

quate stimuli, *e. g.*, for sight, would not give us all the visual qualities of *objects*, even to externality and figure, which *light waves* are capable of giving us.

We saw above that McDougall advances in favor of the doctrine of specific energies the Helmholtz theories of visual and auditory processes, which he says offer the best explanation of the facts. We do not intend to enter into a discussion of the relative merits of the various theories of color sensations. Space will not permit. But we consider the Hering theory, which allows at least *two processes* for each structural element, far superior to that of Helmholtz. It affords a *better* explanation for the phenomena of color blindness, peripheral and faint light vision, the psychical primariness of blue and yellow, etc. Moreover, it has been demonstrated that the same cone can give rise to any or all of the sensations, red, green, and violet. This fact seems favorable to Meisling's vibratory theory, as well as incompatible with the doctrine of a specific process.

As Wundt very well remarks, "Many senses have no distinct sensory elements corresponding to different sensational qualities"—at least these have not been pointed out. This is especially true of smell, but holds to a lesser or greater extent of taste, vision, and even hearing, unless one adopts the Helmholtz theory of auditory processes. This theory may be seriously questioned; but even if true, it can scarcely afford an argument in favor of specific energies; because it may be replied that "the different qualities of the sensations are due not to any original specific *attribute* of nerve fibers or other sensory elements, but to the way in which single nerve fibers are *connected* with end organs," etc. The processes in these fibers and their connections, which may, perhaps, be called *specific functions*, depend upon external impressions, and this dependence is localized at the *periphery*.

When advocates of the doctrine of specific energies analyze sensations to obtain elementary qualities and ascribe to each of these a specific quality of nerve process, they overlook the fact that we have no definite criterion of the primariness of a sensation. The gray obtained by mixing colors has psychically no similarity whatever to the colors, *e. g.*, red and green, of which it is composed. How do we know that red may not itself consist of two or more equally dissimilar sensations? In fact Wundt's principle of the connection of elements would lead us to believe this; and physiologically it appears true. Our criterion of the primariness of red must then be a physical one —the simplicity of the etheric oscillations corresponding to this sensation. Here again we see external stimuli and not nerve process as the ultimate determining factor. This physical simplicity may cause (in fact *does* cause) excitation in a physiologically complex

system. Hence it does not militate against the principle of connection of elements.

Myers points out that "our tonal sensations are the result of a fusion between various primordial elements of which we must always remain ignorant." This is true if we accept the Helmholtz theory; for according to it, pitch depends upon the position of the most intensely stimulated fiber, and we *never* experience the result of stimulating a *single basilar fiber.* This is another illustration of the principle of connection of elements, and the dependence of quality of sensation upon peripheral as well as other elements.

Münsterberg's "action theory" can, we think, be used as an argument against specific nerve energies. At least it harmonizes very well with the view we have adopted and with Wundt's principle of connection of elements. According to this theory, sensory processes are attended by consciousness only when they discharge into actions. In other words, sensation depends upon motor reactions to external stimuli or objects. This seems to be the logical conclusion of Wundt's principle; for this reaction or motor attitude is determined by an inherited or developed *connection of elements.* The specific quality of sensations, then, is nothing more than the specific attitude we assume as determined by the motor discharge or rather by the whole sensory-motor arc. The chemical or physical process is, thus, the same in all nervous substance. There is no inexplicable difference here. This seems more intelligible, less fraught with difficulties, and more in accord with facts than the doctrine of specific energies in Müller's and McDougall's sense. We say in McDougall's sense because this theory does not deny "specific energies," if by the term is meant the *specific function* of a given sensory motor arc or connection, which function may, however, be changed or modified by incorporation into a larger system or by vicarious functioning, as mentioned above.

The action theory, it may be said, ascribes the *quality* of sensations to the *sensory path* and its ending; but, we answer, vividness, intensity, facilitation, etc., depend on the motor discharge, and without these there would be no quality, for these are *attributes* of the quality, and in any case the action theory may not, of course, be infallible in all respects.

A difficult question may be raised, viz.: Why is it that on loss of a sense organ, we still retain the corresponding imagery, while a cortical lesion in a specific area annihilates it? We sometimes forget that there is an important difference between a memory-image and a sensation. McDougall says, "An image resembles the sensation of which it is the representation or reproduction in every respect save that it lacks the vividness of the sensation." The image seems to

lack the tangibleness or feeling of *present* existence that accompanies the sensation. This, then, must be the quality contributed by the sense organ; for every element in the sensory-motor connection contributes its quota. Of course we must remember that without the sense organ there could be no sensations or images; and without external stimuli there would *have been no sense* organs. After a certain sensory-motor arc has been responding for a considerable time with a definite motor attitude to certain external stimuli, if the peripheral portion, the retina, *e. g.*, be then removed, the remaining part of the arc will continue by virtue of adaptation to respond in the *accustomed* manner, when excited by overflows from other arcs or systems with which it has been previously connected. The sensory-motor connections are intact. There is nothing to prevent discharge into *action*. The result is imagery (in this case visual) which, as before said, lacks certain important qualities of sensations, either because it involves but part of the arc or because the impulse can never be so great as that initiated by external stimuli, without which the motor reaction and hence the imagery would have been impossible; for the reaction that underlies the imagery is due to adaptations arising from the *habitual* assumption of the attitude. The doctrine of specific nerve energies, as we mentioned above, renders an explanation of imagery difficult if not impossible. McDougall's two theories seem to us inconsistent. He finds it difficult to explain how the seats of the physiological processes can be identical or partially identical and the resulting psychical phenomena different; and we find him hinting at the action theory, when he says, "Their motor tendencies are the same, the cortical excitement in both cases issues from the cortex by the same efferent paths."

Now, if instead of a sensory organ being removed, there is a lesion in a definite cortical area, *e. g.*, occipital lobe, how is it that imagery is lost? The answer to this follows from what we have said. In the former case the sensory-motor *connections* were intact; now they are severed. The motor discharge is, therefore, impossible. Hence, there can be no reaction or motor attitude and no imagery or sensations. New connections are sometimes formed and the lost sense thus regained. This is called by Wundt "the principle of vicarious function," and is itself a strong argument against specific energy.

In spite of McDougall's assertions to the contrary, we consider association inexplicable on the hypothesis of specific energy. The connection of absolutely unlike processes forever remains an enigma, while association by similarity of motor attitude or reaction seems quite intelligible; and his principle of "*strict* localization of cerebral functions," which of course *logically follows* from the "doctrine of

specific energies,'' is held by very few physiologists of the present day and still remains to be proved.

In conclusion the results of an interesting experiment performed upon cats by Langley and Anderson may be cited against the doctrine of specific energies. The cervical sympathetic nerve *contracts* the blood vessels of the submaxillary gland; the chorda tympani dilates these vessels. The cervical sympathetic was joined at its peripheral end to the chorda tympani. After union and regeneration, stimulation of the cervical sympathetic caused *dilation* of the vessels This proves that a vaso-constrictor fiber can become a vaso-dilator fiber; and that whether contraction or dilation of the blood vessels occurs depends upon the mode of nerve ending. The experiment, of course, was performed upon efferent fibers, but it is not therefore without weight in a consideration of this problem; and it is of especial value in refuting the theory that the seat of the specific energy is in the nerve fibers.

J. W. BRIDGES.

McGILL UNIVERSITY.

IS INVERSION A VALID INFERENCE?

TO the old immediate inferences recent writers add inversion. The inverse of All S is P is Some S is not P. Of No S is P the inverse is Some $\bar{S}$ is P. I and O have no inverse.

Inversion violates the fundamental principle of logic and common sense that we should not go beyond the evidence. Every conclusion, in order to be valid, must be rigidly limited to the content of the premises. Its content must not be greater than that of the premises, and it must not be of a different kind. Now $\bar{S}$, the contradictory of S, is an infinite term greater than S, for it includes all the universe[1] other than S. True, it is limited by the word *Some* in the conclusion, but that fails to make the reasoning good, because $\bar{S}$ is different in kind from S. An ordinary illicit process of the minor term is indeed cured by writing *Some* in the conclusion, as in the following example: No birds are viviparous; all birds are bipeds; therefore no bipeds are viviparous. The minor term is illicit, but the fault is easily cured by writing, Some bipeds are not viviparous. But the inverse also begins with *Some.* Why, then, is it still at fault? Simply because $\bar{S}$ is different in kind. Bipeds are the same two-legged creatures in the conclusion as in the minor premise; but every possible $\bar{S}$ differs from any possible S. Let S stand for ruminants; then $\bar{S}$ will represent non-ruminants. As lambs differ from

[1] Universe here means universe of discourse.